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Phase IIB Operational Test Plan and Procedures of Commercially Available Radio Frequency Identification (RFID) Systems for Baggage Identification, Tracking and Security Applications

Continental Airlines Trial

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16. Abstract

The Operational Test for the Continental Airlines Trial will be used to evaluate those RFID systems that have the potential to accomplish baggage identification, tracking and security requirements in an operational environment utilizing handheld readers, and belt/ramp readers.

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EXECUTIVE SUMMARY

The increasing importance of commercial airline passenger and baggage security, combined with the need to sort and track ever larger numbers of passenger baggage quickly and accurately, have led to the search for more efficient methods of performing the baggage sortation, tracking and security functions. Any tool used to facilitate these functions must be able to rapidly and reliably process, reconcile and track passenger and baggage information. Without this capability, flight delays and increased operational costs are likely to result. Passenger inconvenience could lead to decreased tolerance of airline security regulations and loss of confidence in the air transport industry.

Phase I RFID Testing

In 1997, the FAA sponsored the initial phase of testing of commercially available RFID systems for the support of passenger/baggage matching and baggage sortation functions. Vendor RFID systems underwent Qualification Testing; those that passed this level of testing entered Operational Testing in paired domestic/international airports. Of particular concern in initial Operational Testing were the following characteristics of the candidate systems:

- Performance
- Reliability
- Electromagnetic compatibility (EMC) with airline, airport and aircraft operations and systems
- Compatibility with airport communications restrictions (power, frequency)
- Technical and operational approach to supporting passenger/baggage matching tracking and sortation functions

Operational Testing was conducted in conjunction with sponsor airlines and airports, as well as with the cooperation of a Baggage Reconciliation System (BRS) provider. The test results clearly demonstrated the feasibility of using RF technology to support baggage identification, tracking and security functions. Several systems showed high levels of baggage identification performance, even in suboptimal operational environments.

Phase II RFID Testing

The successful initial phase of feasibility testing led to this current (second) phase of testing – the Integrated System Test. The Operational Test for this second phase is to be conducted in four stages at different combinations of airport sites. Each test stage will focus on specific portions of the end-to-end identification, tracking and security functions.

The first stage, Phase IIA, was conducted at the Frankfurt Airport (Germany) in April of 1999 in cooperation with United Airlines, and with the participation of RF vendors Texas Instruments and Omron Electronics, Inc. The tests there encompassed the passenger baggage check-in process (bag tag encoding) and the reconciliation of the baggage in the baggage make-up rooms (reading the encoded tags).

This second stage of tests, Phase IIB, will take place jointly at the San Antonio, Texas airport and the Houston, Texas airport in cooperation with Continental Airlines. In this stage, the tests will expand to include belt readers and ramp readers, and will involve tail-to-tail baggage transfers. The test will include participation by the following vendors:

Confidence International (Sweden) – System Integrator

Texas Instruments (Texas) – RFID Inlays

Philips (United Kingdom) – RFID Inlays

FEIG Electronic GmbH (Germany) – Belt/Ramp Readers

Flughafen Frankfurt am Main Aviation Ground Services (Germany) – BRS

IER (Texas, France) – Bag Tag Printers

idSystems (United Kingdom) – Printer read/write module

Microlise Engineering Limited (United Kingdom) – Handheld Readers

Moore Research Corporation (New York) – Bag Tag Labels

Sihl GmbH (Germany) – Bag Tag Labels

The third stage of testing, Phase IIC, will take place at two domestic airports and possibly one foreign airport. The domestic airports will be the Miami, Florida Airport and JFK Airport in New York. The foreign airport would be the Tel Aviv, Israel Airport. This stage will expand to include the test of a reusable container tracking system with RF "seals", and testing of varying RFID system frequencies. These tests will be done in conjunction with Tower Airlines.

The fourth stage of testing, Phase IID, will include the test of both disposable and reusable RF bag tags, and international interline transfer of baggage. It will be conducted in conjunction with United Airlines at both domestic and foreign airports; these sites have yet to be named.

<u>Phase IIB Testing</u>

This document addresses only the plan and procedures for the second stage of Operational Test at the San Antonio and Houston Airports. It addresses specific tests to determine:

- The capability of RFID systems to reliably and consistently encode bag tags with baggage RFID information in an operational airport environment
- The capability of RFID systems to reliably and consistently read RFID data from encoded bag tags in an operational airport environment
- The ability of RFID bag tags to withstand the normal rigors of baggage handling without deterioration or failure

1. INTRODUCTION

1.1 Background

The increasing importance of commercial airline passenger and baggage security, combined with the need to sort and track ever larger numbers of passenger baggage quickly and accurately, have led to the search for more efficient methods of performing the baggage sortation, tracking and security functions. Any tool used to facilitate these functions must be able to rapidly and reliably process, reconcile and track passenger and baggage information. Without this capability, flight delays and increased operational costs are likely to result. Passenger inconvenience could lead to decreased tolerance of airline security regulations and loss of confidence in the air transport industry.

Phase I Testing

In 1997, the FAA sponsored the initial phase of testing of commercially available RFID systems for the support of passenger/baggage matching and baggage sortation functions. The initial phase had two stages. Stage one was Qualification Testing. Its objective was to qualify vendor RFID products and systems, in a controlled laboratory environment, to:

- Operate within the physical and operational constraints associated with airline and airport environments
- Perform the functional requirements associated with baggage sortation and passenger/baggage match security objectives in the airline and airport environment, without degradation of existing electronic systems

The RFID systems which passed Qualification Testing subsequently entered Stage Two of initial testing, which consisted of Operational Testing in paired domestic/international airports. Of particular concern in initial Operational Testing were the following characteristics of the candidate systems:

- Performance
- Reliability
- Electromagnetic compatibility (EMC) with airline, airport and aircraft operations and systems
- Compatibility with airport communications restrictions (power, frequency)
- Technical and operational approach to supporting passenger/baggage matching and sortation functions

Operational Testing was conducted in conjunction with sponsor airlines and airports, as well as with the cooperation of a Baggage Reconciliation System (BRS) provider. The test results clearly demonstrated the feasibility of using RF technology to support passenger/baggage matching and sortation functions. Several systems showed high levels of baggage identification performance, even in suboptimal operational environments. In addition, there were a number of suggested approaches for improving system performance, which were identified during the first phase of testing.

Phase II Testing

The successful initial phase of feasibility testing of the candidate RFID systems led to this current (second) phase of testing – the Integrated System Test. The Operational Test for this second phase will be conducted in four stages at different combinations of airport sites. Each test stage will focus on specific portions of the end-to-end identification, tracking and security functions.

The first stage, Phase IIA, was conducted at the Frankfurt Airport (Germany) in cooperation with United Airlines, and with the participation of RF vendors Texas Instruments and Omron Electronics, Inc. The tests there encompassed the passenger baggage check-in process (bag tag encoding) and the reconciliation of the baggage in the baggage make-up rooms (reading the encoded tags).

This second stage of tests, Phase IIB, will take place jointly at the San Antonio, Texas airport and the Houston, Texas airport in cooperation with Continental Airlines. In this stage, the tests will expand to include belt readers and ramp readers, and will involve tail-to-tail baggage transfers. The test will include participation by the following vendors:

Confidence International (Sweden) – System Integrator
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The fourth stage of testing, Phase IID, will include the test of both disposable and reusable RF bag tags, and international interline transfer of baggage. It will be conducted in conjunction with United Airlines at both domestic and foreign airports; these sites have yet to be named.

This document addresses only the plan and procedures for the second stage of Operational Test at the San Antonio and Houston Airports. Subsequent test stages will be addressed individually in separate documents.

1.2 Purpose

The objective of the Operational Test of the RFID systems is to demonstrate the technical and operational feasibility of using RFID technology to conduct baggage and passenger tracking in a complete, real-time end-to-end implementation. The specific Operational Test areas of concern are:

- Compatibility with available physical space for installation
- Ability to interface with test systems
- RFID systems electromagnetic compatibility (EMC) demonstrated with operational airline, airport and aircraft operations and systems
- Compatibility with communications restrictions for power and frequency both domestically and internationally
- RFID systems' technical and operational approach to support the passenger/baggage sorting and reconciliation function within operational environments

1.3 Scope

The Operational Test of vendor provided, commercially available RFID systems will be conducted at selected domestic and international airports in cooperation with sponsor airlines. Candidate RFID systems will be installed and tested at these sites under normal operational conditions. Operational requirements demand not only that the candidate RFID systems perform specific communications functions, but that these systems also possess the capability to:

- Withstand repetitive cycles of sustained operations with little to no maintenance
- Perform in a physically demanding environment
- Not degrade the existing operational electronic environment with additional Radio Frequency Interference (RFI)/Electromagnetic Interference (EMI)

As candidate RFID systems are installed at the test sites, all control and interface functions will be exercised to assure proper operation with the test equipment, and with the interfacing airport systems.

2. REFERENCE DOCUMENTS

DOT/FAA/AR-97/39	Qualification Test Plan (QTP) of Commercially Available Radio Frequency Identification (RFID) Systems for Positive Passenger Baggage Match (PPBM) Applications, June 1997
DOT/FAA/AR-97/44	Qualification Test Procedures (QTP) of Commercially Available Radio Frequency Identification (RFID) Systems for Positive Passenger Baggage Match (PPBM) Applications, June 1997
DOT/FAA/AR-97/40	Operational Test Plan (OTP) of Commercially Available

	Radio Frequency Identification (RFID) Systems for Positive Passenger Baggage Match (PPBM) Applications, June 1997
DOT/FAA/AR-97/45	Operational Test Procedures (OTP) of Commercially Available Radio Frequency Identification (RFID) Systems for Positive Passenger Baggage Match (PPBM) Applications, June 1997
DOT/FAA/AR-98/2	Operational Test Report of Commercially Available Radio Frequency Identification (RFID) Systems for Potential Positive Passenger Baggage Match (PPBM) Applications – Results Not Correlated to Vendors, June 1997
DOT/FAA/AR-98/102	Operational Test Report of Commercially Available Radio Frequency Identification (RFID) Systems for Potential Positive Passenger Baggage Match (PPBM) Applications, November 1997
DOT/FAA/AR-98/XX	Phase II Qualification Test Plan and Procedures (QTP) of Commercially Available Radio Frequency Identification (RFID) Systems for Baggage Identification, Tracking and Security Applications, October 1998
DOT/FAA/AR-98/XX	Phase II Operational Test Plan and Procedures of Commercially Available Radio Frequency Identification (RFID) Systems for Baggage Identification, Tracking and Security Applications, United Airlines Trial, March 1999
DOT/FAA/AR-99/XX	Operational Test Report, Phase IIA Operational Test of Commercially Available Radio Frequency Identification (RFID) Systems for Baggage Identification, Tracking and Security Applications; United Airlines Trial; Frankfurt, Germany; June 1999
DOT/FAA/AR-99/XX	Phase IIB Qualification Test of Commercially Available Radio Frequency Identification (RFID) Systems for Baggage Identification, Tracking and Security Applications; Continental Airlines Trial; San Antonio and Houston, Texas; July, 1999

3. SYSTEM DESCRIPTION

3.1 Test Approach overview

This set of operational tests will be conducted at two different airports simultaneously: the San Antonio International Airport, Houston's George Bush Intercontinental Airport, both in Texas. Figure 3.1 shows a diagram of the test components and their interfaces. The test baggage will be on Continental Airlines flights originating in San Antonio and traveling to Houston. Some of the test bags will arrive in Houston as their final destination. Other test bags will be loaded onto connecting Continental flights in Houston, and will go on to other final destinations.

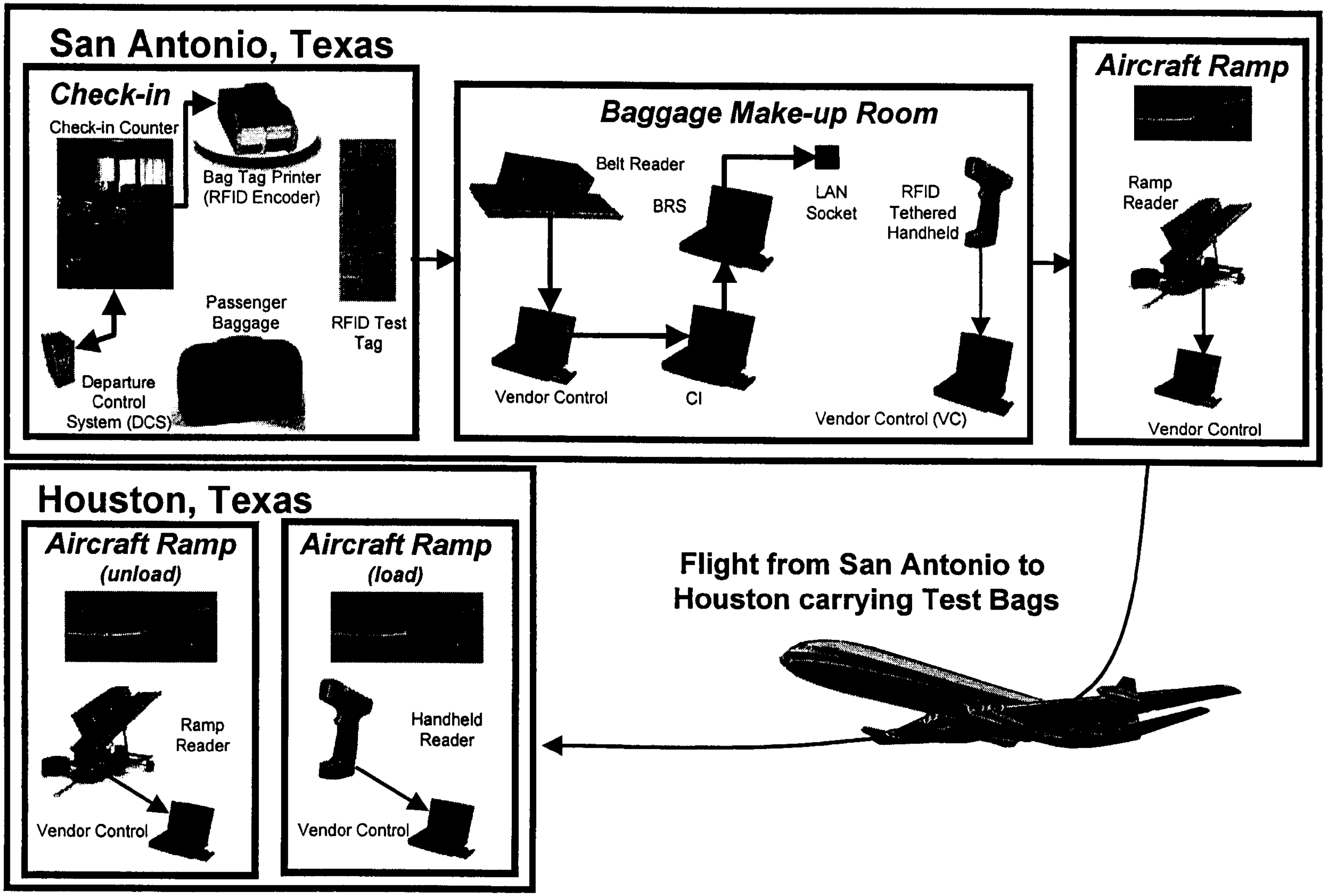


Figure 3.1 Operational Test System Components and Interfaces, San Antonio and Houston Test Sites

These tests will include:

In San Antonio:

- Check-in and tagging of test bags
- Reading of RFID bag tags on the delivery belt using an RFID belt-mounted reader, and in the baggage make-up room using RFID handheld readers
- Reconciliation of the test bags with the passenger data in the baggage make-up room
- Reading of RFID bag tags on the loading ramp into the aircraft departing from San Antonio using an RFID ramp-mounted reader

In Houston:

- Reading of RFID bag tags on the unloading ramp from aircraft arriving from San Antonio using an RFID ramp-mounted reader
- Reading of RFID bag tags on the loading ramp to connecting aircraft leaving Houston using RFID handheld readers

There will be no processing of tags on any bags once they leave the Houston Airport.

There are two RFID inlay providers participating in these tests: Philips Technology and Texas Instruments (TI). Confidence International will be the systems integrator for each of these vendors.

There will also be two paper tag vendors taking part in the tests: Moore Research Corporation and Sihl GmbH. Each RFID vendor's inlay will be tested with each paper tag type, producing four vendor/paper combinations:

- Philips/Moore
- Philips/Sihl
- TI/Moore
- TI/Sihl

The number of test tags produced for the tests is 2500 of each RFID inlay/paper combination, for a total of 10,000 test tags. Every bag on the approximately 10 selected daily flights from San Antonio to Houston will be tagged with a test tag. Two days of testing will initially be allocated for each vendor/paper combination, resulting in eight test days. The objective, however, will be to use all 10,000 tags in the tests; so if eight days of flights do not result in 10,000 tagged bags, more test days will be added to use up the remaining tags.

In San Antonio, the baggage operations will be conducted as usual. The only difference will be that the bag tags affixed to the checked test baggage at check-in will contain RF-encoded data, as well as barcode data, identifying the bag. The bags will move to the baggage make-up room, where they will pass through an RFID belt reader. This reader will automatically read the bag tags and transmit the results to the BRS for reconciliation with the passenger data. In addition, the bag tags will be read with an RFID handheld reader operated by the usual Continental baggage handler, and this data will be stored for later analysis.

The test bags will then be transported to the appropriate aircraft ramp for loading. As the bags are being moved along the conveyor belt on the ramp loader, they will pass through an RFID ramp reader to be automatically read once more before being loaded onto the aircraft. This data will also be stored for later analysis.

In Houston, test bags from the flights arriving from San Antonio will pass through an RFID ramp reader as they are unloaded from the aircraft. The ramp reader will automatically read the test bag tags, and store the resulting tag data.

A portion of the arriving test bags will be going to connecting flights in Houston. Prior to the dispersal of these bags to the appropriate flights, the selection will have been made of the top four connecting flights departing from Houston with respect to the number of test bags going on the flight. At the aircraft ramp of each of these four flights, the test bags will be read with an RFID handheld reader as they are loaded onto the aircraft. The reader will be operated by a Continental baggage handler, and this data will be stored.

All reading of the test bag tags – by belt reader, by ramp reader, and by handheld reader – will be monitored by test personnel and observations will be recorded and time-tagged. The data resulting from all of the readings will be correlated and analyzed offline.

3.2 System Overview

This section provides an overview of the entire complement of equipment that will be used to conduct the Phase IIB Operational Test. Detailed information on each component within these system categories is provided in Section 4.2.2, Test Resources Required. Refer to Figure 3.1 for the diagram of these components and their interfaces. The components that make up this test system fall into four categories:

1. <u>The candidate systems under test</u> – This includes each of the vendor RFID systems whose performance is being tested. For the tests conducted at San Antonio and Houston Airports, a candidate RFID system will consist of the following components:

    - RFID Bag Tags – The RFID bag tags will consist of an RFID inlay laminated into a bag tag. Each vendor's inlays will be incorporated into two different tag paper types for test purposes
    - Modified Bag Tag Printer – The modified bag tag printer is a barcode label (bag tag) printer outfitted with an RF tag Reader/Programmer module
    - Handheld RFID Reader – This is a handheld unit that can be used in the baggage make-up area and on the ramp to manually read the RFID bag tags
    - Belt/Ramp RFID Reader – This is a reader that is mounted over the belt, or over the loading/unloading ramps which transport the baggage to and from the aircraft baggage compartment. It allows RFID bag tags to be read as the bags move along the belt or ramp under the reader

- Vendor Control (VC) – This consists of a laptop PC which hosts the vendor's control software. It is used to provide an interface to the various readers, and to collect and store the read results from the tests

2. The control/interface test hardware and software – This includes all of the hardware and software that has been customized to allow the test team to interface the RFID systems with the airline/airport systems, and to control the test processes and data collection. It consists of the following components:

   Control/Interface (CI) system. The CI is an FAA-provided computer (PC laptop) with software developed to provide the necessary test interfaces, and to collect and manage the test data. The CI performs the following test functions:

   - Stores tag read results from vendor systems
   - Provides the interface between the vendor RFID belt reader VC and the airport Baggage Reconciliation System (BRS); see Section 3b below
   - Performs automatic data reduction and analysis

3. The interfacing airport and airline systems – These are the systems that must communicate information to/from the vendor RFID systems. These include:

   - Departure Control System (DCS) – The DCS is the airline host computer, which records and manages the baggage data associated with the passenger check-in process. The DCS produces a formatted message containing passenger/baggage identification and departure/arrival information, which is sent to the BRS
   - BRS – The BRS is a database software system, which supports: tracking and reconciling of checked baggage to ensure a proper match between passengers and baggage; and optimization of aircraft baggage loading. The data from this system will be used to reconcile the baggage in the baggage make-up room. The BRS interfaces with the DCS and the RFID systems under test (via the CI, in the latter case)

4. Additional airport and airline systems – These are any other airport systems that are essential to the baggage processing sequence of events. They include:

   - Conveyor Belt – The conveyor belt regularly used at the baggage handling area of San Antonio Airport, for Continental Airlines flights, will be used in the usual manner to move the bags from the check-in stations to the baggage make-up room. This component will not interface with any of the other test components
   - Ramp Loader/Unloader – This is a moveable loading device which transports the baggage to or from the aircraft cargo hold via a moving conveyor belt. It is used at the aircraft ramp areas

3.3 Interfaces Overview

The Operational Test interfaces are summarized in Table 3.1 and shown in Figure 3.1.

Table 3.1 Phase IIB Operational Test System Interfaces

Interface	Description
Modified Bag Tag Printer ⇐ DCS	The Modified Bag Tag Printer connects directly to the DCS. This Check-in Reader/Programmer is a barcode label (bag tag) printer with an RFID encoder mounted inside.
Handheld/Belt/Ramp RFID Readers ⇒ Vendor Control	The Vendor Control will receive and record bag tag and time stamp data from the Handheld, the Belt and the Ramp RFID Readers.
Vendor Control ⇒ CI	The Vendor Control will pass the recorded RFID bag tag data to the CI, which will correctly format the data for transmission to the BRS.
CI ⇒ BRS	The CI acts as the interface between the RFID system and the BRS. The CI will send the formatted data to the BRS, so that the baggage data can be reconciled with the passenger data.
DCS ⇒ BRS	The BRS receives baggage/passenger data from the DCS to reconcile with baggage data read in the baggage make-up room.

4. TEST PROGRAM DESCRIPTION

4.1 Sequence of Test Events

4.1.1 Pre-Test Checks

San Antonio. There are three areas of the San Antonio airport where test equipment will be used: The Continental check-in counters, the Continental baggage make-up room, and the ramp area for the departing aircraft.

Check-In Counters. At check-in, special bag tags will be used which contain an RFID inlay (the flexible set of components forming the medium for information storage and RF transfer of license plate data), allowing RFID data to be encoded in the bag tag. These bag tags will be marked visually so that they can be readily identified as test tags by all test participants; in all other respects they will look like the normal barcode bag tags. These bag tags will still be imprinted with a barcode identification in addition to the encoding of the RFID data. The RFID data will consist of the aviation industry's standardized ten-digit International Air Transport Association (IATA) license plate number.

The bag tag printers normally used will have been replaced with a version modified to process these special bag tags and to encode the tags with RFID data when they are printed. These modified printers will undergo testing at a laboratory run by EDS (a subcontractor to Continental) in Houston prior to their delivery to the test site in San Antonio. During these laboratory tests the printer interface with the DCS will be exercised as well as the printing of the RFID bag tags. After testing at the laboratory has been completed, and the results approved by the FAA test team, these printers will be installed at the San Antonio airport Continental check-in area and tested again by Continental Airlines, the FAA test team or Continental's designated agent prior to the operational tests. Before operational testing begins, the FAA and support contractor test personnel will verify that test tag supplies are sufficient for the test.

Baggage Make-Up Room. Several pieces of test equipment must be installed and tested in the baggage make-up room prior to the start of the operational tests.

- 64K LAN Line. This communication line will be installed and tested by Continental a week prior to the start of operational tests. It will be used to transmit passenger/baggage data from the DCS to the BRS for baggage reconciliation
- BRS. The BRS, hosted by a laptop PC, will be tested in the baggage make-up room a week prior to the start of the operational tests. This will be performed by Flughafen Frankfurt/Main AG (FAG) (this same BRS was previously validated during the Phase IIA testing). Part of the check-out testing will include a check of the BRS interface with the installed LAN
- RFID Belt Reader. The belt reader will be installed on the conveyor belt in the baggage make-up room and tested by Confidence/FEIG three to five days prior to the beginning of operational tests. The belt reader has successfully completed qualification testing. The installation and checkout will include an interface to a vendor control (VC) unit (laptop PC) that will be used during the operational tests to collect and record the tag data that is read
- RFID Handheld Reader. A handheld reader that will be used in the baggage make-up room will be tested at the test site by Confidence prior to the operational tests to verify that it is able to read RFID bag tags correctly. Qualification testing has been successfully completed on these units. Its interface to a second VC unit (separate from the unit connected to the belt reader) will also be tested. There is no installation required for this equipment
- Vendor Control Units. Both of the VC units being used to interface to the RFID readers will be tested by Confidence in the baggage make-up room prior to the start of operational tests. These tests will ensure that the units are accurately capturing and transmitting bag tag data. No installation is required for this equipment
- The FAA CI will be tested in the baggage make-up room by FAA test personnel to verify that its interfaces to the belt reader VC unit, and to the BRS, are functioning correctly. The tests will also verify that the CI is accurately receiving, storing, formatting and transmitting the bag tag data. There is no installation required for this equipment

Aircraft Ramp. The only piece of equipment to be installed at the ramp area is the RFID ramp reader. This reader will be installed on the mobile ramp loader and tested by Confidence/FEIG three to five days prior to the beginning of operational tests. The ramp reader has successfully completed validation testing. The checkout will include the verification of the interface to a VC unit. The VC unit will also be tested prior to operational tests, but there is no installation required for the VC.

Houston. There are two areas of the Houston airport where test equipment will be used: the ramp area for the arriving aircraft, and the ramp areas for the departing aircraft.

<u>Aircraft Ramp – Arriving Aircraft</u>. The equipment to be used at the arriving aircraft ramp is an RFID ramp reader which is identical to the one to be used at the San Antonio departure ramp. It will be mounted over the conveyor belt on the mobile ramp loader and tested by Confidence/FEIG three to five days prior to operational testing. Part of the test will be to ensure that the ramp reader can correctly interface to a VC unit by sending the data read from the RFID bag tags.

<u>Aircraft Ramp – Departing Aircraft</u>. The equipment to be used at the departing (connecting) aircraft ramps will consist of a self-contained RFID handheld reader. There is no installation required for this equipment. The handheld readers will all be tested prior to operational test to verify that they can accurately read the RFID bag tags.

4.1.2 Test Events

4.1.2.1 San Antonio

<u>Check-In Counter</u>. As passengers check in for the designated test flights, their checked baggage will be tagged with the test bag tags. Each of these bag tags will have a barcode printed on it and the RFID chip that it contains will be encoded with the unique ten-digit license plate number that is assigned to the particular bag. This will be accomplished in the same tag-printing process. If RF encoding fails, a visual indication such as "RF VOID" will be printed on the bag tag. The airline agent will then put this bag tag aside and issue a new bag tag for the bag being checked. Test personnel will retrieve all failed bag tags for later analysis, and will record the time and location (printer number) of the failure as well as a description of the failure.

The check-in and bag tagging will be done by airline personnel in the normal manner. The bag tag identification data will automatically be entered into the airline DCS, as normal. FAA and support contractor test personnel will monitor the check-in process and will record the circumstances of any discrepancies or problems with the check-in process or with the equipment.

The checked test bags will be sent via the conveyor belt to the appropriate baggage make-up room. The airline DCS will automatically send a Baggage Source Message (BSM) to the BRS in the baggage make-up room. The BSM contains baggage identification data and passenger departure/arrival information that is used by the BRS to determine the disposition of the baggage for a given flight.

At some point after the flight check-in is complete, the block of bag tag identification data associated with that flight will be downloaded from the BRS for later analysis by the FAA test personnel. In addition, any "failed" tags will be scanned with the RFID handheld readers and examined in an attempt to determine the reason for failure.

<u>Baggage Make-Up Room</u>. As each checked test bag arrives in the baggage make-up room on the conveyor belt, it will pass through the RFID belt reader (for the system under test) which is

mounted over the belt. The belt reader will automatically read the RFID bag tag on the test bag, sending the resulting 10-digit license plate number to the VC. The VC will store the bag tag data or the indication of an attempted read. Test personnel will monitor the belt reader, and will record any disruptions, discrepancies, or read failures, noting the time and the circumstances.

The VC will send the license plate number from the bag tag to the CI, which will format this data for transmission to the BRS. The BRS will reconcile the tag data with the passenger data received from the DCS and display either a "Load" or "No Load" message depending upon whether the bag was matched to a passenger boarding the flight. This message will be for test purposes only; all test bags will continue through the normal loading process regardless of their Load/No-Load status. All of the Load/No-Load data will be stored by the BRS. After all test bags have been processed, test personnel will download this data from the BRS for subsequent analysis.

After having passed through the belt reader, each test bag will then be read again by Continental baggage handling personnel using a handheld RFID reader for the system under test. The baggage handler's operation of the handheld reader will be observed by test personnel, and any discrepancies recorded. If the bag tag is not read correctly on the first attempt, this will be noted by test personnel and the baggage handling personnel will attempt to read it a second time. If the second attempt fails, the baggage will be processed as usual, and test personnel will cite the RFID bag tag as a "Failed RF Read", noting the time, the operator of the handheld reader, and the circumstances. All RFID data read from the bag tags will be sent to the VC, which will record the results of the read along with a time stamp of its occurrence. After all test bags have been processed, this data will be downloaded for later analysis.

Once the baggage has been processed for the departing aircraft, the test personnel will look at the final destinations for the baggage connecting in Houston. It will determine the four departing flights from Houston which will be carrying the largest number of test bags. The test personnel in San Antonio will communicate by phone the flight numbers of these four flights to the test personnel in Houston. This will allow the Houston test personnel to position themselves at the appropriate departure ramps for reading of the test bag tags as the baggage is loaded onto the connecting flights.

Departing Aircraft Ramp. When baggage designated for the departing test flight is delivered to the ramp area for loading, it will be placed on the conveyor belt of the mobile ramp loader. As the test bags travel up toward the aircraft, they will pass through the RFID ramp reader mounted over the belt. The ramp reader will automatically read the RFID bag tags on the baggage. The reader will pass the 10-digit license plate number from the bag tags to the associated VC, which will store this data or the indication of an attempted read, along with a time stamp of the reading. Test personnel will observe this process and record any anomalies or discrepancies in the process, along with the time and the circumstances associated with them. After all baggage has been loaded, the stored bag tag data will be downloaded by test personnel for later analysis.

4.1.2.2 Houston

Arriving Aircraft Ramp. As baggage is unloaded from the arriving test flight from San Antonio, it is placed on the conveyor belt of a mobile ramp loader. The ramp loader will have mounted on it a ramp RFID reader similar to the one used on the departing aircraft ramp loader in San Antonio. The ramp reader will automatically read the RFID bag tags as they pass beneath it. It will send the results of the reading to the associated VC. The VC will record the 10-digit license plate number from the bag tag, or the indication of an attempted read. Along with this data it will store a time tag of the reading. Test personnel will observe this process and record any disruptions or discrepancies, the time of occurrence and the associated circumstances. After all baggage has been unloaded from the aircraft, the bag tag data will be downloaded from the VC for later analysis.

Departing Aircraft Ramps (4). When baggage is ready for loading onto a connecting flight in Houston, it will be placed onto the conveyor belt of a mobile ramp loader in the departing aircraft ramp area. Because the exact departure areas will not be known until shortly before the flight is to be loaded, handheld RFID readers will be used at these sites to read the RFID bag tags. The handheld readers will be operated by airline baggage handling personnel. This process will be observed by test personnel, who will record any anomalies or discrepancies in the process, as well as the time of occurrence and the circumstances surrounding it. The operator will attempt to read each bag tag as it moves up the belt into the aircraft. If the first attempt is unsuccessful, the test personnel will note this. A second attempt will then be made. If the second read attempt is still unsuccessful, the failure will be documented and the bag will be loaded onto the aircraft.

For each read attempt, the reader will record the resulting data or the indication of an attempted read, along with a time stamp of each reading. After all baggage has been loaded, the bag tag data from the handheld reader will be downloaded to the VC, to be further downloaded to the CI for later analysis.

4.1.3 Activities Leading to Test

The following activities will be completed before the start of operational testing.

Manufacture of RFID Bag Tags. The bag tag manufacturers who will produce bag tags containing the RFID inlays are Moore Research Corporation and Sihl GmbH. Each of these manufacturers will produce 2500 tags with Philips inlays and 2500 tags with TI inlays, so that there will be a total of 10,000 tags available for the operational tests. Each type of tag will have undergone qualification testing before the start of operational testing to ensure that the RFID bag tags will not hamper the normal tag-printing and check-in process.

Bag Tag Printer Modifications. The printers normally used by Continental at the check-in counters to print the bag tags are made by IER Corporation. For the purposes of these tests, a designated number of printers of the same type will undergo modification in order to allow them to process bag tags containing an RF chip, and to encode identification data onto the chip. RFID vendors will submit specifications for necessary changes to IER to allow these changes to be made and tested prior to the transfer of equipment to San Antonio. Confidence will also loan to

IER a handheld RFID reader to allow IER to verify the readability of the test tags after the printer has processed them.

RFID Ramp/Belt Reader Development. FEIG Electronics will develop both the RFID belt and ramp readers. These readers will be custom manufactured and configured for the belt and ramp loaders used during these tests. Each belt and ramp reader will have undergone qualification testing prior to installation at the operational test site.

Handheld Reader Modifications. Modifications will be made to barcode handheld readers provided by Microlise Engineering. These readers will be outfitted with an RFID read/write module (idSystems) and antenna to allow reading of the RFID bag tags. Each RFID handheld reader will have undergone qualification testing prior to use at the operational test site.

CI Development. FAA support contractor personnel will customize the software required for the CI test equipment to allow it to interface with the VC units and with the BRS. This software will be tested prior to its use in the operational tests.

Factory Testing of Vendor RFID Readers and Controllers. Each RFID vendor participating in the tests will be responsible for conducting factory testing of each type of reader being used in the operational tests. This includes the handheld readers and the belt/ramp readers (the belt and ramp readers use the same reader component attached to different mounting structures). The readers will be tested with the interfacing VC. The factory tests will verify that these units can be expected to operate properly in the operational test environment.

Equipment Transfer to San Antonio/Houston. All equipment and supplies necessary for operational testing which are not already on site will be sent to San Antonio and Houston the week before the scheduled test dates. This includes:

- Modified bag tag printers (San Antonio only)
- Test tag stock (San Antonio only)
- CI test system (San Antonio only)
- RFID vendor equipment (for systems under test)

4.2 Test Environment

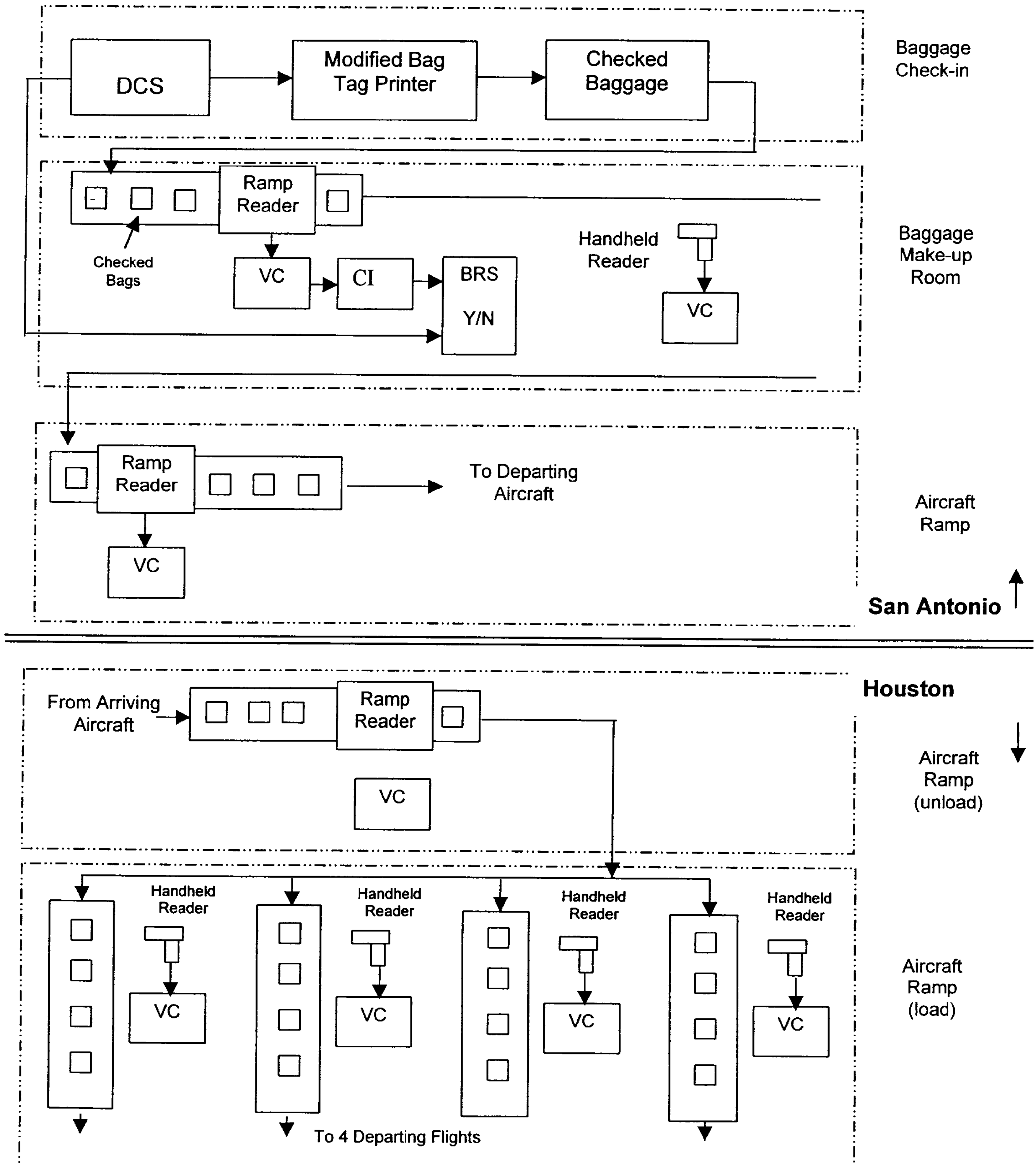
4.2.1 Test Facilities

A block diagram depicting the overall test configuration and test facilities is shown in Figure 4.1. It depicts the locations of test activities at each of the test sites. For the San Antonio site, the diagram shows the test equipment and the flow of baggage from the Baggage Check-In through the Baggage Make-Up Room and on to the Aircraft Ramp for loading. For the Houston site, the diagram shows the test equipment and processing of baggage from the Aircraft Ramp of the arriving aircraft to the Aircraft Ramps of the four departing flights. Each of these areas is discussed in the following paragraphs.

4.2.1.1 San Antonio Airport

4.2.1.1.1 Check-In Stations

There will be no visible changes to the stations at the Continental check-in counter. The modified bag tag printers will be a direct substitution for the current printers. The agents' terminals will remain the same, as will the terminal interfaces to the printers. The agents will use the printers in the normal way.



4.2.1.1 San Antonio Airport

Figure 4.1 Overall Test Configuration Block Diagram

The test personnel monitoring the tests at this location will be located behind the counters, so that they are able to observe the actions of the check-in agents and the functioning of the printers. A block diagram of the check-in station is shown in Figure 4.2.

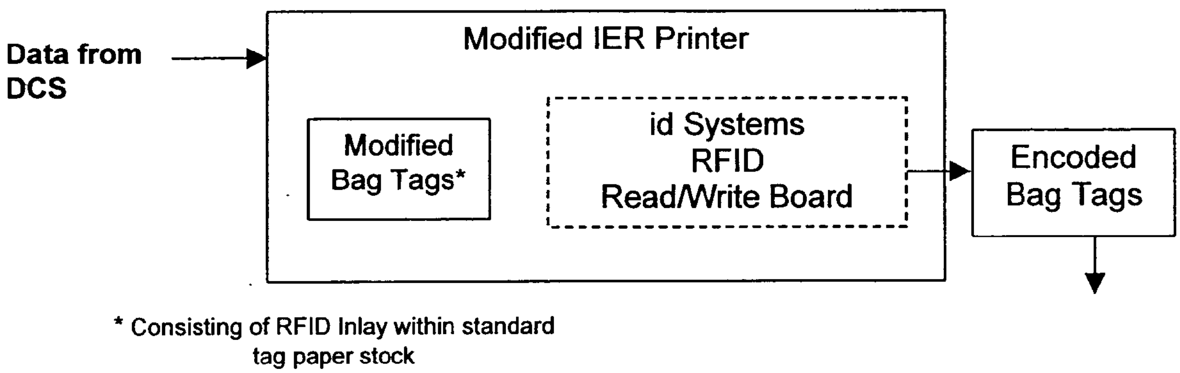


Figure 4.2 Check-In Station Block Diagram

4.2.1.1.2 Baggage Make-Up Room

The following elements will be part of the operational test in the baggage make-up room, as seen in Figure 4.3 and listed below:

- Conveyor belt entering the make-up area (from the sortation area). This belt transports the checked baggage from its originating point at the check-in station to the baggage sortation area, and then to the appropriate make-up room
- Belt Reader. The RFID belt reader will be mounted over the conveyor belt so that test bags passing under it will have their RFID bag tags read automatically. It will have an interface to a VC unit, which will store the data coming from the reader
- VC #1. The first Vendor Control unit will interface to the belt reader so that it can receive the bag tag data that is read and record it for later analysis. It then sends the data from tags that have been read to the CI for subsequent transmission to the BRS
- CI. The Control/Interface test support equipment will interface to VC #1, receiving the bag tag data from the belt reader. The CI also records a time stamp for each attempted read. The CI will then format this data and transmit it to the BRS
- LAN Connection. A LAN line will be installed with access in the baggage make-up room. This is to provide a means of communication between the DCS and the BRS which will be used in the baggage make-up room

- BRS. The BRS software is hosted on a laptop PC. This system will connect to the LAN via the LAN socket in the baggage make-up room. It will receive passenger/baggage data from the DCS via this connection, and perform the baggage reconciliation function, resulting in a Load/No-Load declaration
- Handheld Reader. A handheld RFID reader will also be used in the baggage make-up room. It will be tethered to its own VC for data collection and storage of the bag tag data
- VC #2. This VC is identical to VC #1, except for its interface with the handheld reader

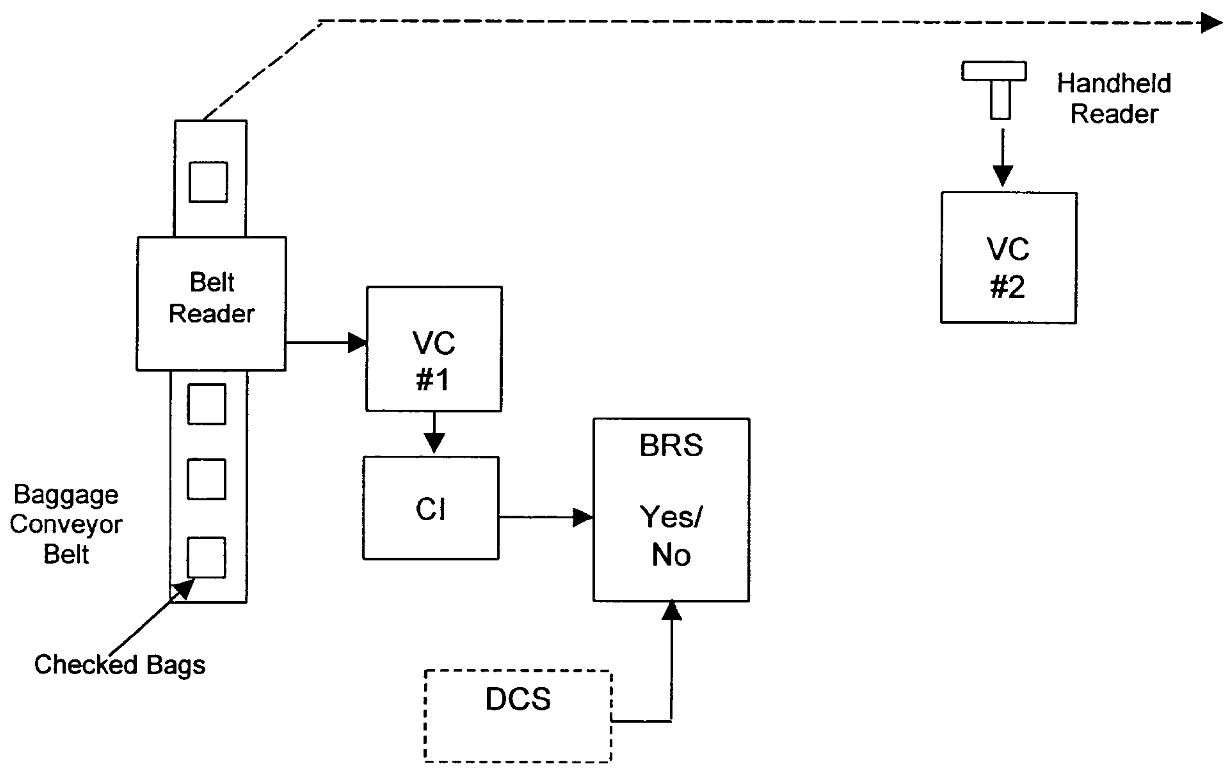


Figure 4.3 Baggage Make-Up Room Diagram

4.2.1.1.3 Departure Aircraft Ramp

The configuration of the test equipment at the departure aircraft ramp in San Antonio is shown in Figure 4.4. It consists of the following elements:

- Mobile Aircraft Ramp Loader. The ramp loader can be driven to any aircraft arrival or departure area. Its conveyor belt moves the checked baggage from the ground level up to the aircraft cargo hold for loading

- Ramp Reader. The ramp RFID reader will be mounted over the ramp loader's conveyor belt. As the checked baggage passes under the reader, the RFID bag tags will be read automatically on their way into the aircraft. The reader will interface to a VC, which will store the data that the ramp reader obtains from the bag tags
- VC. This unit is identical to the other VCs being used in the baggage make-up room. It will interface with the ramp reader

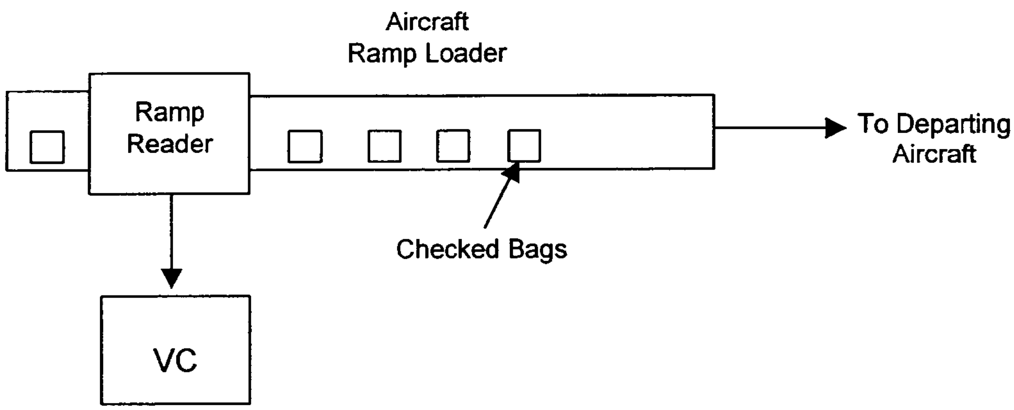


Figure 4.4 Departure Aircraft Ramp Block Diagram (San Antonio)

4.2.1.2 Houston Airport

4.2.1.2.1 Arrival Aircraft Ramp

The test configuration for the arrival aircraft ramp area is the same as that of the departure aircraft ramp area in San Antonio. The only difference is that the checked baggage moves down the inclined conveyor belt from the aircraft to the ground instead of up from the ground to the aircraft. Figure 4.5 shows this test configuration. See Section 4.2.1.1.3 for descriptions of the components and their interfaces.

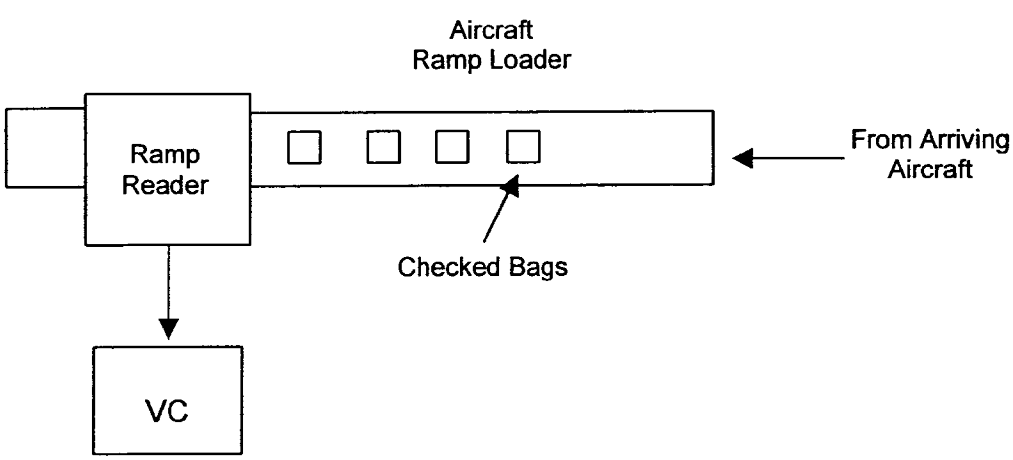


Figure 4.5 Arrival Aircraft Ramp Block Diagram (Houston)

4.2.1.2.2 Departure Aircraft Ramps (Connecting Aircraft)

The test configuration for the departure aircraft ramps in Houston is shown in Figure 4.6. It consists of the following elements:

- Mobile Aircraft Ramp Loader. This equipment is the same as that used in the departure aircraft ramp area in San Antonio and described in Section 4.2.1.1.3
- Handheld Reader. A handheld reader will be used to read the RFID bag tags as they move along the ramp loader conveyor belt into the aircraft. The reader will be operated by Continental baggage handling personnel. The reader will later interface to a VC which will record the bag tag data that is read
- VC. This unit is identical to the other VCs being used in the various test areas. It will interface with the handheld reader

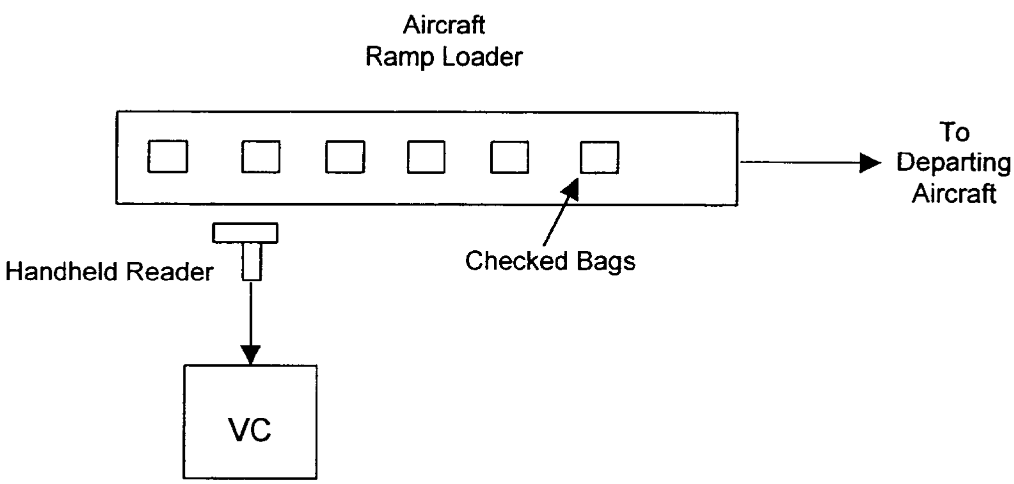


Figure 4.6 Departing Aircraft Block Diagram (Houston)

4.2.2 Test Resources Required

4.2.2.1 Candidate Systems Under Test

The candidate RFID systems under test will consist of RFID inlays embedded in paper bag tags, modified RFID bag tag printers, RFID handheld bag tag readers, and RFID belt/ramp readers. The RFID inlays will be incorporated into currently used paper barcode bag tags to produce RF encodeable and readable bag tags. Both Philips and TI RFID inlays will be used. The bag tag printers used at the check-in sites will be modified to include an RFID board capable of printing standard barcodes as well as encoding and reading RFID bag tags. Handheld readers used in the baggage make-up room as well as on the ramps of departing flights will be modified to read RFID bag tags. Belt/ramp readers connected to vendor control units will be used to automatically read and store RFID bag tag information as baggage is delivered to the baggage make-up room and as it is transferred to and from the aircraft.

4.2.2.1.1 Bag Tags

4.2.2.1.1.1 RFID Inlays

TI RFID Inlay

The TI RFID inlay is a very thin, read/write memory, Radio Frequency (RF) transponder fabricated on a polymer tape substrate. When integrated into label manufacturing processes it produces disposable labels for consumable labeling and identification of items. Data is stored in and read from a 256-bit, non-volatile user memory contained on the inlay. The RFID inlay can be factory programmed with a Simultaneous Identification algorithm that allows multiple transponders to be read simultaneously. The technical specifications for the RFID inlay are shown in Table 4.1

Table 4.1 Technical Specifications for the TI RFID Inlay

RFID Inlay	Technical Specification
RF Communication Frequency	13.56 MHz
Memory	256 bit programmable user memory (8x32 bit blocks)
Antenna Size	45 x 45 mm or 45 x 76 mm
Operating Temperature	-25^0C to $+70^0C$
Uplink/downlink data rates	26.7 kBd/6.2 to 9 kBd secured with CRC
RX modulation	Pulse Width coded AM 100%
TX frequencies	Manchester encoded, $A=f_c$ +/- 423.75 kHz, B= f_c +/-484.29 kHz Low bit: transition A to B, High bit: transition B to A
Thickness	Chip and contact: 0.375 mm All other areas: 0.085 mm
Base Material	Substrate: Polyethylentherephtalate (PET) Conductive area: Aluminum

Philips RFID Inlay

The inlay used by Philips is a thin read/write RF transponder. It is incorporated into the manufacture of the bag tags to produce disposable labels for identification of baggage. Data is stored in and read from a 512-bit EE-PROM contained on the inlay. The technical specifications for this inlay are shown in Table 4.2

Table 4.2 Technical Specifications for Philips RFID Inlay

Parameter	Technical Specification
MECHANICAL	
Width	48 + 0.6mm/- 0.0mm
Length per piece	96 ± 0.5mm (next step 78 ± 0.5mm)
Thickness of electronic part	259 um
Overall thickness of copper antenna	47 um
ELECTRICAL	
Communication frequency	13.56 MHz
Memory	512-bit EE-PROM

4.2.2.1.1.2 Paper Tags

Paper bag tags manufactured by both Moore Research Corporation of New York and Sihl GmbH of Germany will be used in the testing. Each bag tag manufacturer will incorporate both the TI and Philips RFID inlays into their tags to produce self-adhesive barcode bag tags with RFID inlays embedded in them.

4.2.2.1.2 Bag Tag Printers

The bag tag printers used in these operational tests will be modified versions of the IER 512B printer. These units will incorporate an RFID board (an OEM module) supplied by id Systems, Ltd. This board will enable the printer to encode both the TI and Philips RFID inlays for the test tags.

The IER printer is a direct thermal printer for self-adhesive labels, tickets and tags. Table 4.3 contains details of the printer characteristics.

Table 4.3 IER Printer Characteristics

Characteristic	Specification
Print Technology	Direct Thermal
Print Speed	Up to 7 inches per second
Print Resolution	203 dpi (8 x 8 dots per mm)
Memory	2 MB flash PROM, 512 kB SRAM standard
Interface	RS232
Size	203 mm x 220 mm x 445 mm
Voltage	85 to 264 VAC (Auto switching), 50/60 Hz

The id Systems RFID board that will be incorporated into the printers provides the capability to read from and write to 13.56 MHz tags from Philips Semiconductors (I.CODE) and Texas Instruments (Tag-it). This board is intended for embedding within portable computers and handheld data terminals, but may also be used with a number of motherboards to provide a wide range of additional interfaces, including user memory, real time clock, RS-232 interface, keypad and digital I/O. It provides the following features:

- An In-System-Programmable component which allows firmware to be readily upgraded for enhanced functionality and support of new tag types
- Support of a wide range of antennas (PCB and air coil), with on-board tuning
- Single supply operation (+5V) at low current (200mA when reading)
- Low power modes, with board wake-up on external digital command and serial activity
- Serial interface (at TTL levels) with tri-state serial buffer for total isolation within embedded applications
- Serial protocol, including optional direct ASCII output of tag code on successful read
- Two software controlled digital outputs for LED's (on or off board)
- I^2C port for interfacing with external hardware (not supported in firmware)
- Small board size (approximately 70 x 52 x 9 mm), with EMI/RFI screen fitted

The operation of the printers will have been verified prior to their installation at San Antonio to ensure that they are able to process the RFID/barcode test bag tags for purposes of operational test. The printers will be modified so that they can cleanly replace the normal printers; i.e., their installation will not require any modifications to any other interfacing equipment.

4.2.2.1.3 RFID Handheld Readers

Handheld readers manufactured by Microlise Engineering will be used for the testing. These handheld readers are barcode readers that will be modified to read RFID bag tags with the incorporation of an RFID board supplied by id Systems, Ltd. The id Systems RFID board that will be incorporated into the readers provides the capability to read from and write to 13.56 MHz tags used by both TI and Philips. Three handheld reader models will be used for the testing; the Rugged Scanner 4, the Tracer 4, and the Dexter 4. The characteristics of each are shown in Table 4.4.

Table 4.4 Characteristics of Handheld Readers

Characteristic	Rugged Scanner 4	Tracer 4	Dexter 4
Dimensions	225 mm (height) 71 mm (width) 158 mm (depth)	225 mm (height) 97 mm (width) 205 mm (long)	225 mm (height) 87 mm (width) 55 mm (depth
Weight	550 g	706 g	470 g
Power	Battery	Lithium-ion battery	Lithium-ion battery
Interface	RS 232	RS 232	RS 232

4.2.2.1.4 RFID Belt/Ramp Reader

The baggage conveyor belt and aircraft ramp loader will have automatic RFID bag tag readers supplied by FEIG Electronic GmbH. The readers for both the conveyor belt and ramp loader will be the same. They will consist of three antennas and electronics for reading the RFID bag tags. Two of the antennas will be located on each side of the moving belt, while the third antenna is located under the belt. The system is configured as shown in Figure 4.7. This antenna configuration allows the automatic reading of the RFID bag tags regardless of orientation.

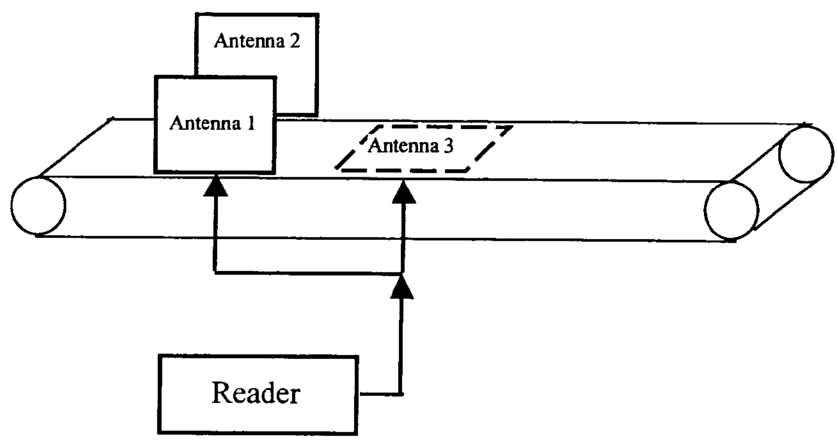


Figure 4.7 Belt/Ramp Reader Configuration

The characteristics of the belt/ramp reader are shown in table 4.5.

Table 4.5 Belt/Ramp Reader Characteristics

Characteristic	Specification
Electronics Housing	
Dimensions	300 x 300 x 120 mm
Power	60 VA
Interface	RS232
Side Antennas	0.9 m x 0.7 m x 0.1 m
Distance between side antennas	0.87 m
Bottom Antenna	0.9 m x 0.6m
Distance between side and bottom antenna	1.0 m
Operating Frequency	13.56 MHz
Max read/write distance	1.20 m

4.2.2.2 Airport/Airline Systems

4.2.2.2.1 DCS

As the passengers are being checked in, their flight and baggage information is entered into the airline's DCS. The DCS generates a standardized 10-digit bar code (known as the license plate number), used for sortation and security purposes, for each item that is checked in. This code is stored in the DCS, and is printed on the bag tag, which gets attached to the checked bag. The DCS then sends a BSM, containing the passenger departure, connection and arrival information, along with the license plate identification numbers of any checked bags, to the BRS. This passenger/baggage information can then be reconciled with the baggage identification data in the BRS in order to identify any security issues.

4.2.2.2.2 BRS

The BRS developed by Flughafen Frankfurt/Main AG (FAG), is a computerized baggage reconciliation system with multiple airline-host connectivity. It consists of a host computer connected via a local area network (LAN) to numerous terminals throughout the airport.

4.2.2.2.3 Conveyor Belt System

The standard conveyor belt system at the San Antonio Airport will be used to transport the test bags from the check-in stations to the baggage make-up room. The RFID bag tag belt reader system, described in paragraph 4.2.2.1.4, will be added to the conveyor belt to automatically read the RFID bag tags on the baggage as it is delivered to the baggage make-up room.

4.2.2.2.4 Ramp Loader/Unloader

The ramp loader is a 660 series manufactured by S&S TUG. It is a vehicle mounted conveyor belt system that can be driven to an aircraft and raised or inclined so that baggage can be loaded onto the aircraft from the ground or vice versa. Characteristics of the ramp loader/unloader are shown in Table 4.6.

Table 4.6 TUG Series 660 Ramp Loader/Unloader Characteristics

Characteristic	Specification
Conveyor Length	294 in
Conveyor Width	34 in
Conveyor Capacity	2000 lb
Conveyor Speeds 1) Gas & Diesel 2) Electric	 45 to 90 feet per minute 10 to 90 feet per minute

4.2.2.3 Test Support Systems

4.2.2.3.1 Control Interface (CI)

The CI consists of customized software, which resides on a Micron TransPort Xpe laptop PC. It provides the interface between the Vendor Control (VC) and the BRS in the baggage make-up room. It uses an RS-232 interface to communicate with both the VC and the BRS. The interface to the BRS is made via an LL500 decoder.

Following the flight check-in portion of the test, a database of all encoded RFID bag tag data (from the bag tags that were encoded and attached to baggage) will be downloaded from the BRS to the CI. During the baggage make-up portion of the test, the belt reader will read each RFID bag tag and transfer the information to the VC. The VC will transfer that data to the CI. The RFID bag tag information will consist of:

- An ASCII start character: @
- Bag tag's ten-digit barcode number
- An ASCII stop character: Carriage Return

The CI will then format the data and forward the formatted information to the BRS via the LL500 Decoder box.

Following completion of the testing, test personnel will use the CI's automated data reduction and analysis capability to analyze the check-in RFID bag tag database along with the database of RFID bag tags from the belt reader, the handheld readers, and the ramp readers for each vendor. The analysis results will determine the performance of the RFID system under test.

4.2.2.3.2 Vendor Control

The VC is a PC with specialized software to control the belt and ramp readers and collect data from the belt, ramp and handheld readers. It will receive and store RFID bag tag data from the belt reader and the handheld reader in the baggage make-up room, from the ramp reader at the departing and arriving aircraft, and from the handheld reader at the tail-to-tail baggage transfer. This data will be downloaded for analysis following the tests. The VC will also interface with the CI to transfer the RFID bag tag data from the conveyor belt reader via the CI to the BRS .

4.2.2.4 Test Personnel

4.2.2.4.1 San Antonio Airport

Personnel from Continental Airlines, the FAA and FAA support contractors, and San Antonio Airport will be required to perform the testing. The following criteria will be used to establish the number of each type of personnel required.

1. Check-in Site Testing
    - Airline Personnel - The airline will provide the number of check-in/ticket agents that are needed and would normally be used for passenger/baggage check-in for the designated test flights
    - FAA and FAA Support Contractor Personnel - The FAA will provide two observers at the check-in test site, to monitor the check-in process and record data
2. Baggage Make-up Room Testing

- Airport Personnel - The airport will provide the number of baggage handlers that are needed and would normally be used for baggage handling for the designated test flights
- FAA and FAA Support Contractor Personnel - The FAA will provide two observers for the belt reader and baggage make-up room test site to monitor the RFID reading process and record data

3. Departure Aircraft Ramp Testing
   - Airport Personnel – The airport will provide the number of baggage handlers that are needed and would normally be used for baggage loading for the designated test flights
   - FAA and FAA Support Contractor Personnel – The FAA will provide one observer at the departure aircraft ramp test site to monitor the baggage loading process and record data

4.2.2.4.2 Houston Airport

1. Arrival Aircraft Ramp Testing
   - Airport Personnel – The airport will provide the number of baggage handlers that are needed and would normally be used for baggage unloading for the designated test flights
   - FAA and FAA Support Contractor Personnel – The FAA will provide one observer at the arrival aircraft ramp test site to monitor the baggage unloading process and record data
2. Tail-to-Tail Aircraft Testing
   - Airport Personnel – The airport will provide the number of baggage handlers that are needed and would normally be used for baggage loading for each of the four designated test flights
   - FAA and FAA Support Contractor Personnel – The FAA will provide one observer at each of the four departing aircraft ramp test sites to monitor the baggage loading process and record data

4.3 Test and Evaluation Description

4.3.1 Test Objective

The objective of this testing is to verify that the RFID technology can be successfully introduced into an actual airport operational environment to perform the baggage identification, tracking and reconciliation function. This testing will focus on the passenger check-in process, the baggage reconciliation process, and the tracking of baggage through tail-to-tail transfers.

4.3.2 Evaluation Criteria

Evaluation of the RFID systems under test will be based on the following factors:

- Encoding rate of success
- Read rate of success

- Operator Impact

4.3.2.1 Encoding Rate of Success

The encoding rate of success is a measure of the RFID systems' capability to correctly encode and print the RFID bag tags. To be effective, the RFID bag tags must be consistently and accurately encoded and printed. Any reduction in system performance compared to current capabilities could impact the workload of airline ticketing/check-in agents, and could cause delays in the passenger check-in process. The encoding rate of success will be based on the percentage of successfully encoded tags printed during the baggage check-in process. The percentage will be determined by dividing the number of successfully encoded tags by the total number of attempted encodings.

4.3.2.2 Read Rate of Success

The read rate of success is a measure of the RFID systems' capability to correctly read the RFID bag tags. The effective use of the RFID bag tags requires that they are able to be accurately read during normal baggage handling without slowing or hindering normal procedures in any way. Bag tag failure, or the inability to read the bag tag, could result in delays in baggage routing, misdirected baggage or lost baggage based on the integrated system concept of operation. The read rate of success will be based on the percentage of successful tag reads during the baggage sorting process. The percentage will be determined by dividing the number of successful bag tag reads by the total number of attempted reads. The read rate will be calculated separately for each individual type of RFID reader.

4.3.2.3 Operator Impact

The operator impact is a measure of any additional functions or operations that must be performed, or any additional time that must be spent in performing the normal operations in order to accomplish RF baggage identification, tracking and reconciliation. To be successful, the RFID system should be able to effectively perform the baggage reconciliation function with minimal or no impact to the functions performed by the airline check-in and the baggage handling personnel. The operator impact will be based on observations made by test personnel during the baggage check-in process, the baggage reconciliation process, and the RF identification of baggage during the usual baggage handling process.

4.3.3 Data Analysis Methods

During operational test of the RFID systems, all test data will be downloaded to the CI for storage. Following the RFID bag tag encoding and printing, accomplished during the passenger/baggage check-in process, the record of all bag tags printed for each flight will be downloaded from the BRS to the CI. To determine the encoding rate of success, the CI will be used to compare the record of all bag tags printed to the test personnel's records of RFID bag tags that failed to print correctly. This ratio will be compiled daily and broken out according to the paper/inlay combination, so that each paper/inlay combination will have an encoding success rate calculated for each day that it was tested. Any inconsistencies or anomalies in the data will be investigated.

RFID data from each VC used in the tests will be downloaded to the CI. Each bag tag record will be annotated with the date and time. This data, along with the test personnel's record of bag tags that failed to read correctly, will be used to determine the read rate of success for each different read event in the test (e.g., reading with the belt reader vs. reading with the handheld reader). Using the data and time stamps for each record will allow calculation of time between bag tag readings; this will provide an indication of the rate at which the tags were being read. The data and read rate of success for each RF reader used will be compared to determine if there is consistency in the data. Any inconsistencies or anomalies in the data will be investigated.

RFID bag tag encoding and reading errors, if any, will be investigated in an attempt to determine the cause of the errors. The encoding errors would prove less difficult to investigate since the failed tags from the check-in site will be available for analysis. Any RFID bag tags that did not read properly in the baggage make-up room would not be available since the bag tags can not be removed, and the cause of the read errors would be more difficult to ascertain.

As a final point of analysis, the test personnel's observations concerning any difficulties with system operation, delays, errors, or other factors that impacted airline/airport personnel and operations will be reviewed and analyzed in an attempt to determine their cause, and to identify possible corrective measures.

5. TEST MANAGEMENT

5.1 Test Management Organization

The Operational Test of vendor provided, commercially available RFID systems is to be conducted by the FAA and support contractor personnel with additional support from RFID system component vendors, and commercial airline and airport personnel.

5.1.1 Test Conduct Teams

The Test Conduct Team* will consist of:

- FAA and support contractor personnel
- Continental Airline personnel
- San Antonio and Houston Airport personnel

* RFID vendor personnel and Confidence personnel will be available at the test sites to provide assistance only in the event of equipment failure or malfunction.

The roles and responsibilities of the test conduct team are as described in paragraph 5.1.2.

5.1.1.1 Roles and Responsibilities

Personnel from the FAA William J. Hughes Technical Center will be responsible for conducting the testing of the RFID systems, including monitoring of the actual tests, test data acquisition, data analysis, and reporting of test results. The FAA, via its support contractor personnel, will provide the CI and software programs necessary for interfacing the CI with the VC and BRS, and for performing the data analysis.

Vendors will provide the RFID inlays for bag tags, the handheld, belt, and ramp RFID bag tag readers, and the VC's. The bag tag manufacturers will provide the integrated RFID bag tags to be used during testing, and the bag tag printer manufacturer will provide the printers to encode/print the integrated RFID bag tags with data. Vendors will be responsible for the proper operation and maintenance of their corresponding system components. Vendors also will provide assistance in any required troubleshooting should system component failures occur.

Airport personnel will provide any information and support necessary for the interface of equipment to the BRS for installation of the modified bag tag printers. They will also perform normal baggage handling functions and will read the bag tags using an RFID handheld reader.

Airline personnel will load each printer with RFID bag tags prior to testing, and perform normal passenger/baggage check-in functions.

5.2 System Configuration Management

Any modifications that may be required to the RFID system under test from its original configuration, prior to completion of all testing for that system, will be documented. Portions of the testing affected by the modifications may be repeated to verify any changes in the test data that may have resulted from those modifications.

5.3 Operational Test Entry Criteria

Prior to the start of operational testing, the following items must be operational and qualified for operational test:

- RFID Bag Tags
- Modified Bag Tag Printers
- RFID Handheld Readers
- RFID Belt Reader
- RFID Ramp Reader
- Vendor Control

Each vendor must supply sufficient quantities of these items, along with information describing system installation and operation. Insufficient quantities of system hardware, non-operational hardware, or the lack of system installation and operation information may result in insufficient or incorrect test data or failure of the system to meet operational requirements.

5.4 Operational Test Execution

All test personnel shall review the test procedures so that they understand the tests that will be performed, how they will be performed, and what data will be collected. The vendor-supplied RFID system components will be installed as directed in the system installation and operation information provided by each vendor, and their operation verified.

Airline and airport personnel who participate in the testing will be briefed on their roles as well as on the operation of that portion of the RFID system that they will be using.

Testing will be performed in accordance with test procedures described in Appendix A. Any apparent abnormalities observed in data recording, test operation, or the recorded data will be investigated to determine the cause, and a determination will be made by the Test Coordinator as to whether a re-test is required.

5.5 Operational Test Exit Criteria

The criteria for successfully completing the operational test will be the determination, based on the test results, that the RFID systems under test are able to effectively and reliably accomplish the baggage identification and reconciliation functions in the airport environment. If any of the systems fail to meet the established criteria, the Test Coordinator shall make a decision as to whether to allow the system to be included in any further testing (if re-testing is needed) or whether the system failed and cannot meet the criteria.

5.6 Operational Test Reports

Upon completion of the operational testing, an Operational Test Report will be developed. The report will detail the results of the operational tests and describe the RFID systems tested, the test schedule and location, the participants, the test objectives, test configuration, the test execution, the hardware and software interfaces, and the data collection and analysis methodology.

5.7 System/Operational Deficiency Reports

Should any RFID system deficiencies or failures occur, the vendors will be notified and will be responsible for the repair, replacement, or maintenance of their respective systems. The occurrence of any failures/deficiencies will be recorded. The vendor will be notified and given the opportunity to investigate and correct the problem. The results of any additional testing or re-testing required will also be recorded. Any remaining performance deficiencies affecting the operation of the systems, which are uncovered as a result of testing, will be documented in the Operational Test Report.

5.8 Operational Test Schedule

The following test schedule is in effect at the time of publication of this document.

TEST EVENTS	September
Equipment Setup & Test	9/13 9/21
Philips/Moore Test	9/22 9/23
TI/Moore Test	9/24 9/25
Philips/Sihl Test	9/26 9/27
TI/Sihl Test	9/28 9/29
Trial Complete	9/30

Figure 5.1 Operational Test Schedule

5.9 Planning Considerations and Limitations

The overriding consideration when conducting the tests is to ensure that the test activities do not impact the normal airline/airport operations. Test personnel are to act as monitors and data collectors only, once testing has begun.

APPENDIX A
TEST PROCEDURES

A.1 CHECK-IN SITE PROCEDURES - SAN ANTONIO (SAT)

A.1.1 Objective

The objective of this test is to verify that RFID bag tags can be successfully and reliably encoded, printed and attached to baggage with no adverse impact to the current airline baggage check-in procedures.

A.1.2 Check-in Site Test Procedures (SAT)

1. The modified bag tag printers will have been installed at designated check-in stations. The assigned airline personnel or their designated agent will load each printer with RFID bag tag stock prior to the start of testing.
2. Each time a new roll is loaded into a printer, record the RFID bag tag type loaded along with the date and time it was loaded onto the appropriate Printer Log sheet. Also, record the first barcode number printed for each new roll.
3. Airline personnel will perform normal passenger/baggage check-in procedures and print RFID bag tags using the modified bag tag printers. They will then attach the RFID bag tags to baggage as it is checked in. If RF encoding fails, a visual indication will be printed on the bag tag.
4. FAA and support contractor personnel will immediately collect any failed bag tags and record the following information on the back of the tag:
   - Time/Date
   - Printer Station
   - Brief description of the failure
5. FAA and support contractor personnel will monitor the baggage check-in process. During check-in, FAA and support contractor personnel will record the following data:
   - Manual count of the total number of valid RFID bag tags issued and placed on delivery belt.
   - Manual count of the total number of valid RFID bag tags issued and <u>not</u> placed on delivery belt (oversize, animal cages, re-booked, etc.)
   - Any errors encountered in printing RFID bag tags
   - Any difficulties encountered with system operation
   - Any observed problems experienced by airline personnel in performing check-in procedures
   - Any observed delays in the check-in process as a result of system operation
   - Any other factors related to the use of the RFID system which affect the check-in process
6. After the check-in process has been completed for the test flight, FAA test personnel will download the data file of printed RFID bag tags issued from the BRS. This will be used for later analysis of the test data, along with the results of the RFID bag tag reading at each location.

A.2 BAGGAGE MAKE-UP ROOM PROCEDURES - SAN ANTONIO (SAT)

A.2.1 Objective

The objectives of this test are:

1. To verify that the Handheld Readers and the RFID bag tags will withstand the normal rigors of baggage handling without failure.

2. To verify that the RFID bag tags can be read dynamically, during the baggage make-up process using a Belt Reader, and via the CI, reliably provide inputs to the BRS.

A.2.2 Baggage Make-Up Room Test Procedures

1. The Control Interface (CI), the Baggage Reconciliation System (BRS) and the Handheld Readers and Belt Reader, each with a Vendor Control (VC), will have been installed in the designated baggage make-up rooms, and will be operational prior to the start of testing.

2. Prior to reaching the final make-up belt, a Belt Reader will automatically read each RFID bag tag. The VC will record each read. The VC will pass the barcode number read from each RFID bag tag to the CI. The CI will format the data and pass it to the BRS. After the make-up process has been completed for the test flight, FAA test personnel will download the data file of bag tags read by the Belt Reader from the interfacing VC. This will be used for later analysis of the test data.

3. Airport personnel will perform normal baggage handling procedures. In addition, airport personnel will also read each bag using a Handheld Reader. The airport personnel will make two attempts to read each RFID bag tag. If the RFID bag tag fails to read after the second attempt the airport personnel will continue processing the bag as normal without any further reads. The Handheld Reader will be connected to a VC. The VC will record each read along with a time stamp.

4. FAA and support contractor personnel will monitor the Baggage Make-up Room process including the Belt Reader and the Handheld Reader operation. During the Baggage Make-up processing, the following data will be recorded:

    - Barcode number of any RFID bag tag that could not be read by the Handheld Reader after the second attempt
    - Barcode number of any RFID bag tag that was not read at all by the Handheld Reader due to any alternate handling procedures for that particular bag
    - Manual count of the total number of bags with test tags sent through the Belt Reader
    - Any read errors resulting from the inability of the handheld RFID reader to read the RFID bag tag
    - Any read errors resulting from erroneous readings by the handheld RFID reader

- Any difficulties encountered with system operation
- Any operator impact resulting from the use of the RFID system
- Any other factors related to the use of the RFID system, which affect the baggage make-up process

5. After the make-up process has been completed for the test flight, FAA test personnel will download the data file of RFID bag tags read by the Handheld Readers from the interfacing VC. This will be used for later analysis of the test data.

A.3 DEPARTURE AIRCRAFT RAMP PROCEDURES - SAN ANTONIO (SAT)

A.3.1 Objective

The objective of this test is to verify that the RFID bag tags can be read dynamically, during the baggage loading process using a Ramp Reader, and via the Vendor Control (VC) reliably record all bag reads.

A.3.2 Departure Aircraft Ramp Test Procedures

1. The Ramp Reader and Vendor Control (VC) will have been installed on the designated ramp loader, and will be operational prior to the start of testing.

2. Airport personnel will perform normal baggage handling procedures at the ramp loader. The Ramp Reader will automatically read the RFID bag tags as the bags move up the ramp and into the aircraft. The VC will record each read along with a time stamp.

3. FAA and support contractor personnel will monitor the loading process. During the loading processing, the following data will be recorded:
    - Manual count of the total number of bags with test tags sent through the Ramp Reader
    - Any difficulties encountered with system operation
    - Any operator impact resulting from the use of the RFID system
    - Any other factors related to the use of the RFID system, which affect the baggage make-up process

4. After the loading process has been completed for the test flight, FAA test personnel will download the data file of RFID bag tags loaded at the aircraft ramp from the VC. This will be used for later analysis of the test data.

A.4 ARRIVAL AIRCRAFT RAMP PROCEDURES - HOUSTON (IAH)

A.4.1 Objective

The objective of this test is to verify that the RFID bag tags can be read dynamically, during the baggage off-loading process using a Ramp Reader, and via the VC reliably record all reads.

A.4.2 Arrival Aircraft Ramp Test Procedures

1. The Ramp Reader and Vendor Control (VC) will have been installed on the designated ramp loader, and will be operational prior to the start of testing.

2. Airport personnel will perform normal baggage handling procedures at the ramp loader. The Ramp Reader will automatically read the RFID bag tags as the bags are unloaded from the aircraft and move down the ramp. The VC will record each read along with a time stamp.

3. FAA and support contractor personnel will monitor the unloading process. During unloading processing, the following data will be recorded:
   - Manual count of the total number of bags with test tags sent through the Ramp Reader
   - Any difficulties encountered with system operation
   - Any operator impact resulting from the use of the RFID system
   - Any other factors related to the use of the RFID system, which affect the baggage make-up process

4. After the unloading process has been completed for the test flight, FAA test personnel will download the data file of RFID bag tags read at the aircraft ramp from the interfacing VC. This will be used for later analysis of the test data.

A.5 TAIL-TO-TAIL AIRCRAFT PROCEDURES - HOUSTON (IAH)

A.5.1 Objective

The objectives of this test are:

1. To verify that the Handheld Readers and the RFID bag tags will withstand the normal rigors of baggage handling without failure.
2. To verify that the tracking of baggage using RFID readers can be accomplished during the Tail-to-Tail transfer process.

A.5.2 Tail-to-Tail Aircraft Test Procedures

1. The Handheld Readers will have been moved to the designated area and will be operational prior to the start of testing.

2. After the departure of each flight from San Antonio, FAA test personnel in San Antonio will contact the FAA test personnel in Houston and provide them with the top 4 (with respect to the number of test bags) connecting flights where baggage will be loaded via the tail-to-tail

process. Based on this information, FAA test personnel in Houston will move a Handheld Reader to the loading ramp for the designated test flights.

3. Airport personnel will perform normal baggage handling procedures at the loading ramp. In addition airport personnel will also read each bag using a Handheld Reader. The airport personnel will make two attempts to read each RFID bag tag. If the RFID bag tag fails to read after the second attempt, the airport personnel will continue processing the bag as normal without any further reads. The handheld reader will record each read along with a time stamp.

4. FAA and support contractor personnel will monitor the loading process. During loading processing, the following data will be recorded:

   - Manual count of bags that did not read
   - Any difficulties encountered with system operation
   - Any operator impact resulting from the use of the RFID system
   - Any other factors related to the use of the RFID system, which affect the baggage make-up process

5. After the loading process has been completed for the test flight, FAA test personnel will download the data file of RFID bag tags read by the Handheld Readers to the interfacing VC. This will then be downloaded to the CI for later analysis of the test data.

APPENDIX B
DATA COLLECTION FORMS

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

BAG TAG PRINTER LOG

Printer ID Number / Check-in Location: ______________________________

Date	Time	RFID Inlay Vendor (TI or Philips)	Paper Tag Vendor (Moore or Sihl)	First Barcode Number

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM – CHECK-IN STATION

Printer ID Number / Check-in Location: ______________________________

Date:	
RFID Inlay: (TI or Philips)	**Paper Tag:** (Moore or Sihl)

Total number of valid RFID tags issued and placed on delivery belt:	
Total number of valid RFID tags issued but "not" placed on delivery belt (i.e. oversized, animal cages, etc.):	
Total number of valid RFID tags issued but "not" processed (i.e. re-booked):	
Total number of RF Void tags:	

Comments:

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM
BAGGAGE MAKE-UP ROOM – HANDHELD READER

Date:	
Total number of bags delivered to baggage make-up room:	

TAGS NOT READ		
Barcode Number	Place a check in the appropriate column	
	Read Failure (2 attempts)	No Read Attempts

Comments:

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM
Baggage Make-Up Room – Conveyor Belt

Date:	Flight:
Number of bags with RFID tags loaded on conveyor belt:	

Comments:

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM – RAMP LOADER (DEPARTING AIRCRAFT)

Date:	**Flight:**
Number of bags with RFID tags loaded on ramp loader:	

Comments:

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM – RAMP LOADER (ARRIVING AIRCRAFT)

Date:	Flight:	
Number of bags with RFID tags loaded on ramp loader:		

Comments:

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM
TAIL-TO-TAIL TRANSFER – HANDHELD READER (DEPARTING AIRCRAFT)

Date:	
Total number of bags delivered to baggage make-up room:	

TAGS NOT READ		
Barcode Number	Place a check in the appropriate column	
	Read Failure (2 attempts)	No Read Attempts

Comments:

PHASE IIB RFID OPERATIONAL TEST
CONTINENTAL AIRLINES TRIAL

DATA COLLECTION FORM – GENERAL INCIDENT LOG

(Record any problems, anomalies or delays)

Incident No.		**DETAILS**
Incident Type*		
Date/Time	**Location**	
Flight No.		
Tag No. (if Tag incident)		
Incident No.		**DETAILS**
Incident Type*		
Date/Time	**Location**	
Flight No.		
Tag No. (if Tag incident)		
Incident No.		**DETAILS**
Incident Type*		
Date/Time	**Location**	
Flight No.		
Tag No. (if Tag incident)		

* Incident Type
B = Belt Reader
M = Miscellaneous / Other
R = Ramp Reader
C = Control Interface
O = Operator
S = BRS
H = Handheld Reader
P = Printer
T = Tag